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EEDI Analysis for Trimaran Feeder at Maluku Waters

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ABSTRACT: The international maritime organization (IMO) has worked since 2009 to minimize harmful gas emissions from marine traffic. Due to its worldwide climate effect, IMO has implemented an energy efficiency design index (EEDI) to monitor and quantify CO2 emissions. Due to 1.0-meter wave height, Maluku waters remain quiet. For transporting from distant, outermost, and border places, feeder ships will work better. The three-body vessel (trimaran) has a vast deck surface and can efficiently feed tiny islands. This study analyzes trimaran vessel EEDI and resistance using Froude number Fr = 0.21 speed and transverse distance S/L = 0.2, 0.3, 0.4, and 0.5. Experimental calculations show a large fluctuation in hull distance. The trimaran ships with S/L=0.5 have the least resistance and essentially equal calculation results to independent trimarans. This shows that the trimaran with a 0.5 hull ratio has little hull interference. For trimaran ships, EEDI estimates suggest operating below Fr=0.21, which meets IMO criteria.

KEYWORDS: EEDI, Trimaran Feeder, Resistance, Experiment, Maluku Waters

I. INTRODUCTION

As a way to move people and goods from one place to another, transportation has a big effect on the progress of society, the nation, and the state. This is because it helps development happen everywhere. In order to facilitate this occurrence, it is imperative to ensure the effective management of various transportation modalities, including marine transportation. The contemporary progress of maritime transportation is intricately linked to the proliferation of technological advancements across diverse regions of Indonesia, enabling the domestic production of ships.

Supply chain efficiency is expected to improve with the demand for feeder vessels that make it easier to move goods to and from remote, border, and peripheral areas. The trimaran vessel, also known as a three-body ship, possesses the advantageous characteristic of a spacious deck area. This attribute enables it to effectively facilitate the transportation of products between islands, serving as both a connecting feeder ship and a means of moving goods between said islands. A feeder ship refers to a relatively smaller vessel in comparison to a larger mother ship, mostly employed for the purpose of transporting and delivering products to several islands. The trimaran ship is a versatile vessel that exhibits favourable attributes in terms of size, ship features, and material composition, making it well-suited for deployment as a feeder ship. This suitability is particularly evident in its ability to effectively enhance inter-island accessibility. Therefore, it is imperative for trimaran vessels to exhibit optimal performance across diverse sea conditions in order to guarantee efficient ship propulsion and assure maritime safety.

Due to the enormous number of commodities that can be transported by big ships and the low per-unit costs of maritime transportation in comparison to those of air transportation, maritime transport continues to be the primary mode of transport on a global scale. It is estimated that around 80% of global commerce in terms of volume and 70% in terms of value is handled by ports and transported by sea [1]. The entire size of the world's commercial fleet has grown significantly over the last decade, leading to an accompanying rise in emissions that have a cumulatively adverse effect on the natural world. Emissions of greenhouse gases (GHG) and carbon dioxide (CO2) as the principal sources of greenhouse gases have a negative impact on agricultural and international commerce [2].

Over the last 40 years, researchers throughout the globe have made significant strides toward their goal of reducing overall ship resistance and, by extension, power consumption. The importance of adopting the right engine technology to produce the largest potential reductions in GHG emissions is highlighted by Lindstad, et al. [8]. Subsequently, Farkas et al. [9] evaluated the fuel savings and CO2 emission reductions that may be realized by applying antifouling coatings with lower roughness to crude oil and bulk carriers as examples. Reducing the engine's speed by 13.6 percent while running on low-sulfur marine gas oil significantly reduced fuel oil consumption and carbon dioxide emissions across the board. Much more energy can be conserved using steam turbines. When compared to low-sulfur marine gas oil, using liquefied natural gas may reduce emissions by up to 49% [10]. The greatest potential for mitigation lies in the use of non-carbon fuels, although this strategy has been the least widely adopted so far. Despite their considerable mitigation potential, the other two options have been widely embraced by the market and should not be retrofitted into a significant section of the fleet at this time [11]. Molland et al. [12] summed up more research toward lowering total vessel resistance and enhancing propulsor efficiency. It is possible to accomplish the latter by modernizing ship hull design and switching to multihull boats like catamarans and trimarans from single-hulled ones.

The use of multihull ships has had a substantial growth in the last forty years across several domains such as ferry transportation, fishing operations, recreational boating, and oceanographic research expeditions [13]. The advantages of these vessels in comparison to monohull vessels are evident, encompassing enhanced layout accommodations, improved transverse stability, and the potential to reduce overall resistance. This reduction in resistance can lead to a decrease in the size of the main engine, resulting in a reduction of CO2 emissions and a lower Energy Efficiency Design Index (EEDI) [14]. A variety of vessel types have been further developed in order to satisfy the specified design specifications. The catamaran and trimaran ideas are among the favored options and are seeing a surge in popularity. As previously indicated by Molland et al. (2013), the catamaran design has attracted considerable attention due to its capacity to provide a bigger deck area while maintaining transverse stability. In recent years, there has been a growing preference for the trimaran hull configuration, characterized by three hulls, due to its advantageous features such as a bigger deck space and enhanced seakeeping capabilities, as compared to the catamaran [15].

The resistance of trimarans may be a complex challenge for ship designers, particularly due to the intricate interaction between the sidehull and mainhull. In order to accurately calculate the scaling of a model ship to a real ship, it is important to possess a comprehensive understanding of the many components that contribute to ship resistance. The resistance of multihull ships is more complicated than that of monohull boats. This is mostly because the interference effects that happen when the ship's hulls touch each other are more complicated. Both computer simulations and experiments were used to look into the trimaran's resistances and powering characteristics, as well as the effects of different outrigger hull shapes. The user's text does not contain any information to rewrite. Previous studies have shown a correlation between the intensity of cross-flow and the level of resistance to interference [17, 18]. In their study [19], discovered that some hull configurations have the potential to significantly decrease wave resistance across different Froude values. Uithof [20] performed a comprehensive investigation that revealed a clear demarcation between the sidehull and mainhull, leading to little or negligible interaction. The modest interaction is seen within the range of S/L 0.4 and 0.5, suggesting that a trimaran with a displacement comparable to that of a monohull may exhibit less resistance and need less main engine power. Numerical and experimental methodologies were used to examine the resistances and power-related attributes of a trimaran while also exploring the impact of outrigger hull configurations.

Figure 1 Maluku Waters

Large ships can't get to some of the Maluku Islands' (Maluku and North Maluku Provinces) more remote islands without support ships (Figure 1). This is why they are so important for sea traffic in those areas. A 2014 report from the Directorate General of Sea Transportation says that most ships that operate in Maluku seas are less than 60 metres long. Ships that move goods from the filling port to the transfer port and then to the mother ship go through a change of ship. This is called a feeder ship. Most of the time, this kind of ship is smaller than an aircraft carrier. In this case, we could say that the feeding ship helps get things to where they need to go.

Big Container

Feeder ship

Figure 2. Load Transfer

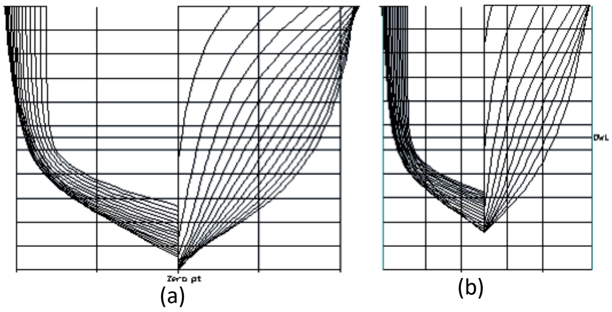
Feeder ships, which are ships between 30 and 35 GT, are used by ships whose shipping paths give entry to other islands (Figure 2). Ships that provide access between islands are often used to move people and goods to and from remote, outermost, and border places to keep things running smoothly. Trimaran ships have a big deck area and low drag, which means that they are both comfortable and good at moving things around and using fuel.

The main purpose of this study is to assess the Energy Efficiency Design Index (EEDI) of a trimaran design.The determination of the resistance of the trimaran model was conducted by experimental testing. The computation of [specific calculation] was conducted in compliance with the International Maritime Organisation (IMO) norms. Moreover, the study aims to enhance the utilisation of multihull boats as a means to mitigate the Energy Efficiency Design Index (EEDI) of operational vessels, hence fostering the advancement of eco-friendly maritime transportation. Moreover, there exists a strong correlation between it and air pollution originating from ships.

II. METHOD

A. Resistance Test

The experimental test was carried out on a tank that belonged to the ITS and had the following dimensions: length (L) of 50 meters, breadth (B) of 3 meters, depth (H) of 2 meters, maximum draft (T) of 1.8 meters, and maximum speed of carriage of 4.0 meters per second. Figure 3 and Table 1 each exhibit the particulars of the model, including its body plan and the environment in which it was created. The experiment was carried out at a variety of speeds (and Froude numbers) as well as space-to-length ratios or clearances (S/L), as indicated in Table 2:



(a) (b)

Figure 3: Body plan of model: mainhull (a) and sidehull (b)

Table 1: Principle particulars of trimaran vessel and model

Dimensi Partikular	unit	trimaran vessel	Model
LOA	m	30.47	1.2525
LPP	m	29.62	1.2178
$B_{Mainhull}$	m	4.07	0.1675
$B_{Sidehull}$	m	2.35	0.0965
B (S/L = 0.2)	m	14.20	0.5836
B (S/L = 0.3)	m	20.13	0.8274
B (S/L = 0.4)	m	26.04	1.0707
B (S/L = 0.5)	m	32.02	1.3166
H	m	2.94	0.1210
T	m	1.62	0.0667
Displacement	ton	100	0.006942

Table 2: Configuration and Various Speed of Test

Froude Numbers (Fr)	Type of ship	Clearance (S/L)
0.15, 0.17, 0.19, 0.21, 0.23, 0.25, 0.27	Trimaran	0.2, 0.3, 0.4, 0.5

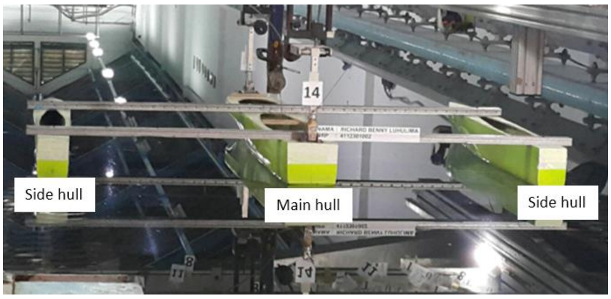


Figure 4: Setting of trimaran model in the towing tank

The improved design elements of a trimaran contribute to a reduction in the amount of resistance that is still there. The near location of the distinct hulls, which leads to interaction in both the total resistance, does, however, result in a new kind of resistance. This is the outcome of the situation. This indicates that the following is a viable option for construction. Imagine a hull with a beam of B being cut in half to create two equal hulls, each of which has a beam of B/2 in addition to a main hull. The overall resistance of the original hull was R_T; however, this resistance has since been split into two equal resistances, which are denoted by the acronyms RTSidehull and RTmainhull. In light of this, the equation for the total resistance may be stated as follows:

$$R_T = 2R_{TSidehull} + R_{TMainhull} \qquad (1)$$

As was previously indicated, the interaction of the waves created by the hulls is caused by the location of the different hulls in relation to the separation (S) between them. This suggests that if the hulls are positioned in such a manner that there is no contact between the hulls, then there would be no interference resistance encountered [5]. This interference resistance may be minimized, removed, and even used to one's benefit if one investigates the differences in separation. Even if there would be a decrease in the hull's efficiency if there was an interference, this brings up an intriguing subject. It is possible to compute this interference resistance in such a way that:

$$R_T = 3R_{THull} + \Delta R_{TV} + \Delta R_{TW} \qquad (2)$$

$$R_T = 3R_{THull} + R_{Interfernce} \qquad (3)$$

where ΔR_{TV} and ΔR_{TW} may be put together as the interference resistance owing to the impacts of the trimaran.

Empirical formulation to estimate the overall resistance of trimaran is not known as of yet and is greatly dependent on the outcomes of the experiments [4].

B. Full Scale Extrapolation

The ship's full-scale calculation is based on the same displacement data, which is obtained through the calculation by using the equation (6) below:

$$\frac{\mathbf{1}}{\boldsymbol{\lambda}} = \frac{\boldsymbol{\rho_{Model}}}{\boldsymbol{\rho_{Ship}}}\left(\frac{\boldsymbol{\nabla_{Model}}}{\boldsymbol{\nabla_{Ship}}}\right)^{\frac{\mathbf{1}}{\mathbf{3}}} \tag{4}$$

Where, $\boldsymbol{\nabla}$ is displacement (kg) and $\boldsymbol{\lambda}$ is scale factor.

All ship models are assumed to have a Gross Tonnage (GT) which is proportional to the displacement of ship

C. EEDI Calculation

The Energy Efficiency Design Index, or EEDI, is a piece of legislation that is being suggested by the International Maritime Organization (IMO) that would make it possible for ships to be assessed for how efficiently they use energy. When designing ships, the EEDI index is a useful tool for calculating how much CO2 the ship will emit for each mile it travels. The EEDI index of the ship should be as low as possible to reduce the total quantity of CO2 emissions. The EEDI is computed with the use of a complex algorithm that takes into account the ship's speed, capacity, and emissions. According to the ICCT's (International Council on Clean Transportation) explanation of what EEDI is and what it is used for, the following equation may be used to produce an estimate of it:

$$EEDI = \frac{P*SFC*CF}{C*v} \text{ gm CO}_2\text{/tonne.mile} \tag{5}$$

Equation (5) says that P is the engine's power at 75% of MCR, measured in kW, and C is the CO2 emission based on the type of fuel used by the given engine. The specific fuel consumption per unit of engine power, as certified by the manufacturer, is given by SFC. The non-dimensional factors f were added to the EEDI approximation to profile for a number of different current systems. vref is the service speed at maximum load, measured in knots; and c is the capacity in deadweight tonnage (DWT) or Gross Tonnage (GT)

III. RESULT AND DISCUSSION

A. Ship Resistance

The test model was tested with configurations of distance between the hulls that varied transversely (S/L). Trimaran hull resistance testing was carried out in a hydrodynamic test pool (towing tank) at Froude speeds (Fr) from 0.15 to 0.27, with three different hull clearance configurations in the transverse direction (clearance, S/L). The test program on the hull model is shown in Table 3. The S/L ratio describes the ratio of the distance between the two hulls (to the center line of the hull) and the length of the hull. The test model is equipped with a 'load cell transducer' measuring instrument to measure the magnitude (force) of resistance.

Table 3. Coefficient Total Resistance ($x10^{-3}$)

Fr	Independent	S/L=0.2	S/L=0.3	S/L=0.4	S/L=0.5
0.15	4.207	4.257	4.248	4.228	4.218
0.17	4.358	5.169	5.108	4.779	4.367
0.19	4.623	5.375	5.246	5.025	4.697
0.21	5.135	5.862	5.605	5.456	5.162
0.23	5.708	6.557	6.288	5.977	5.777
0.25	5.88	6.681	6.581	6.312	6.058
0.27	5.865	6.792	6.728	6.346	6.092

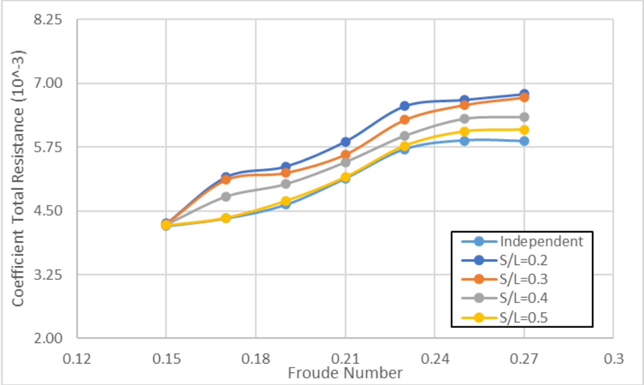


Figure 5 Coefficient Total Resistance ($x10^{-3}$)

The hull's shape is characterised by a flat or thin structure with a length-to-beam ratio (L/B) that is significantly high. In terms of resistance, the contribution of non-wave resistance outweighs that of wave resistance, constituting a larger portion of the total resistance. The phenomenon of viscous resistance, primarily driven by frictional resistance, exhibits a positive correlation with the length of a ship's hull. As the dimensions of the wet area expand, there will be a corresponding increase in the magnitude of the surface friction force. In the context of ship design, it is observed that wave resistance tends to decrease as the length of the ship's hull increases while keeping the displacement constant.

B. EEDI Calculation

The analysis of effective engine power (EHP) also demonstrates a consistent pattern, indicating that trimaran vessels exhibit the lowest power requirements when compared to other types of ships. This is demonstrated in Table 4 and Figure 6 In the context of ship propulsion, it has been observed that a trimaran vessel travelling at a velocity of 12 knots necessitates an energy input of 608.08 kW. In comparison, a catamaran vessel demands 629.16 kW of power, while a monohull vessel necessitates 665.43 kW of power. This observation demonstrates that trimaran vessels possess the benefit of requiring a reduced amount of engine power

Table 4. Power of Ship

	Daya Efektif Mesin/EHP (HP)				
	Trimaran				
Fr	Independen	S/L=0.2	S/L=0.3	S/L=0.4	S/L=0.5
0.15	111.20	119.76	117.09	114.43	111.47
0.17	124.74	145.44	139.44	139.44	128.64
0.19	147.43	175.27	166.77	160.10	154.10
0.21	184.62	218.72	199.69	193.05	188.28
0.23	224.32	251.80	247.80	237.88	220.32

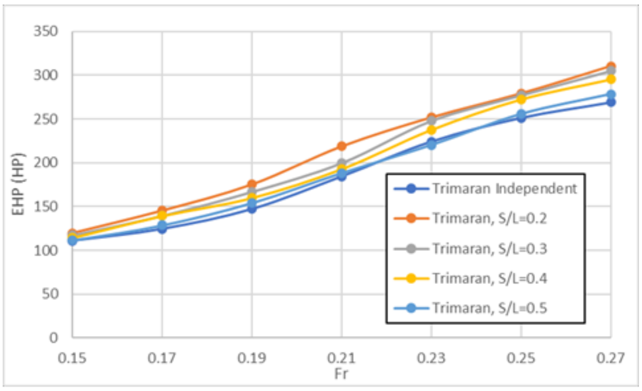


Figure 6. Power of Ship

The Energy Efficiency Design Index (EEDI) can be regarded as a metric for assessing the carbon dioxide (CO2) efficiency of maritime vessels. The equation in power form encompasses both primary and secondary propelling factors, with the primary factor being the capacity of the main ship denoted as tonnes dead weight (DWT), and the secondary factor being the gross tonnage (GT) for trimaran fishing vessels. The user's text is missing. Please provide the text that needs to be rewritten. The calculation results for the trimaran feeder ship are illustrated in Figure 7

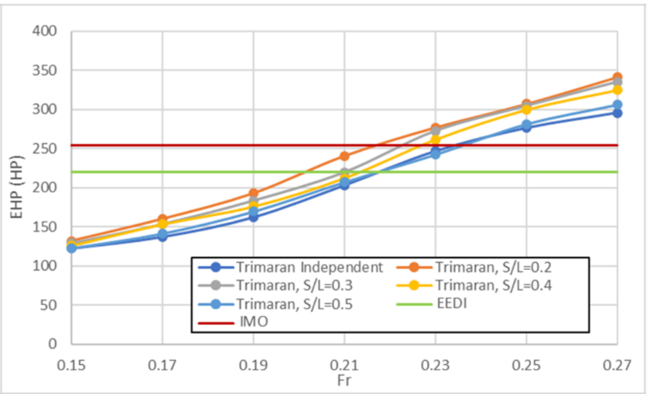


Figure 7 EEDI of Ship

This analysis reveals that the International Maritime Organisation (IMO) regulations specify a permissible energy index of 253.9767 gmCO2/tonne.mile per year. However, the average calculated energy index is found to be 269.5132 gmCO2/tonne.mile per year. This indicates that the observed phenomenon is the excessive emission of pollutants by ships, surpassing the limits set by the International Maritime Organisation.

When determining the energy index, there exists a correlation between the magnitude of the calculated index and the level of pollution incurred. Specifically, as the index number increases, so does the potential for pollution resulting from the ship's activities. There are many ways to reduce and fix the bad effects of ship-related pollution that can be used when building new ships or making changes to old ones. The consideration of economic aspects poses challenges, particularly for ships that have already been constructed, as it influences decision-making processes. There are several strategies that can be employed to decrease the energy index.

CONCLUSIONS

The findings of the experimental calculations indicate that the variation in the distance between the hulls is quite significant. The trimaran ships that have the variation S/L=0.5 have the least amount of resistance when compared to the other variations, and their calculation results are almost identical to those of independent trimarans. This demonstrates that the trimaran with a hull ratio of 0.5 has almost no interference between the hulls.

The results of the calculations done by EEDI for trimaran ships reveal that operations should be advised below Fr=0.21, which is in compliance with IMO requirements.

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